QUARTERLY PROGRESS REPORT
MONTANA DOT "PERFORMANCE PREDICTION MODELS"
JANUARY-MARCH 2005

To: **Susan Sillick, MDT; Jon Watson, MDT**
Contract No.: **MDT HWY-30604-DT**
Contractor: **Fugro Consultants LP**
Contract Period: **June 2001-May 2006**
Prepared By: **Jim Moulthrop, Project Manager**
Date Prepared: **April 18, 2005**

PROJECT OVERVIEW

The overall objective of this research is to develop a design process and performance/distress prediction models that will enable the Montana Department of Transportation (MDT) to use mechanistic-empirical principles for flexible pavement design. The project involves a comprehensive performance monitoring and laboratory-testing program and spans a period of five years.

The specific tasks identified in the work plan are:

PHASE I
- Task 1. Literature Review
- Task 2. Review of MDT Pavement-Related Data
- Task 3. Establish the Experimental Factorials
- Task 4. Develop Work Plan for Monitoring and Testing

PHASE II
- Task 5. Presentation of Work Plan to MDT
- Task 6. Implement Work Plan – Data Collection
- Task 7. Data Analyses and Calibration of Performance Prediction Models
- Task 8. Final Report and Presentation of Results

NOTE: New information for the current month is notated by double-lines to the left of text, tables, or figures.

PHASE I: CURRENT WORK ACTIVITIES AND COMPLETED TASKS

Task 1 – Literature Review

Completed: The literature review summarized the pavement performance models to be considered within this project and was submitted to MDT in October 2001.

Task 2 – Review of MDT Pavement-Related Data

Completed: A review of the available pavement-related data specific to the State of Montana was completed and included in the Task 3 "Experimental Factorial" and Task 4 "Sampling and Testing Plan" submitted to MDT in October 2001.

Planned: Because the LTPP database is updated periodically, to ensure the data is accurate and current, Fugro will perform a one-time final update of the calibration/validation database before the end of the project.

Task 3 – Establish the Experimental Factorials

Completed: The "Minimum Data Elements" report and the "Experimental Factorial" were completed and submitted to MDT in October 2001. The factorial consists of 93 LTPP test sections of which 38 are in the State of Montana and the remaining 55 in neighboring States and Canada. In addition, 10 non-LTPP, supplemental sites were established and included in the factorial: Condon, Deerlodge / Beckhill, Silver City, Roundup, Lavina, Wolf Point, Ft. Belknap, Perma, Geyser, and Hammond.

Task 4 – Develop Work Plan for Monitoring and Testing

Completed: The Monitoring and Testing Work Plan was developed and provided to MDT in October 2001. The document contains the Materials Sampling Plan, the Initial Testing Plan to document the baseline condition of each test site, the Laboratory Testing Plan to define the material properties and layer thickness at each test site, and the Performance Monitoring Plan to document time series data within the 60-month contract period.

Performance Monitoring Plan
The Performance Monitoring Plan was revised in a team meeting in March 2004 and is presented in detail in Table 1:

Table 1 Performance Monitoring Activities

Activity	Available	Planned
Distress Surveys	June 2002, June 2003	June 2005
FWD	August 2001, April 2002, April 2004, April 2005	May 2005
Profile	October 2001, August 2004 (partial)	May 2005

FWD Comparison Study
A comparison study was performed on LTPP sections in Great Falls and Big Timber, Montana (May 6-May 19, 2004) in which MDT LTPP sections were tested in parallel with MDT's FWD equipment and LTPP's FWD equipment. The purpose of this comparison testing was to identify any bias that might exist between the FWDs used to measure deflection data on different test sections that will be used on this project. The hypothesis was that there is no bias between the two devices.

The comparisons in measured deflection and backcalculated moduli between the MDT and LTPP FWD equipment led to the following conclusions:

- In the great majority of the cases the LTPP equipment measured higher deflections compared to the MDT equipment for all sensors and all drop heights. The bias was higher for sensor 1 and decreased as the distance from the load (sensor 1) increased.

- In terms of backcalculated moduli values, a clear bias between the two pieces of equipment is observed only for the modulus of the asphalt concrete (surface) layer. For the base and subgrade layers, overall there is good agreement between the MDT and LTPP backcalculated values.

- The ratio E_{MDT}/E_{LTPP} for the asphalt concrete layer ranges from a value of 1.5 at 300,000 psi to 1.0 at 2,000,000 psi. A simple correlation was developed and is given in Equation 1:

$$E_{LTPP} = 0.1975 \cdot E_{MDT}^{1.1064} \quad (R^2 = 0.90) \tag{1}$$

- Further testing is not necessary.

A similar study for profile equipment is desirable and will be carried out in 2005.

The plots presented in our October 2004 Monthly Report for the FWD comparison study showed a rather poor correlation between the two pieces of equipment when looking at the back-calculated modulus of the subgrade. For clarification purposes, the plot is analyzed again in more detail. Figure 1 shows the plot included in the October 2004 report.

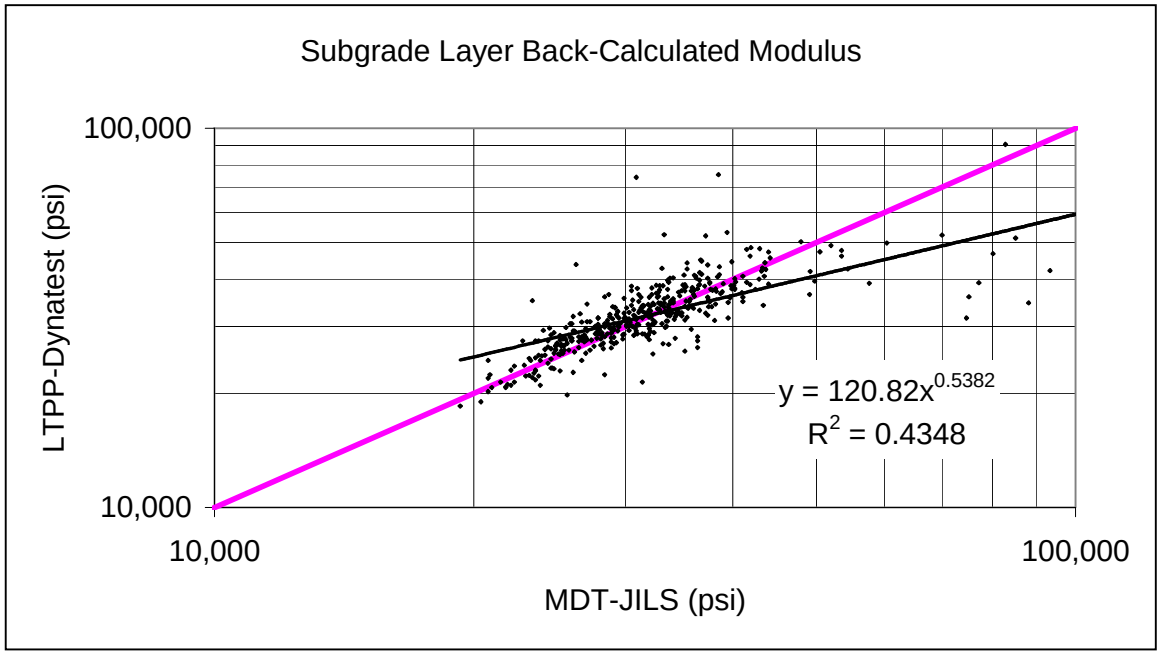


Figure 1. Back-Calculated Subgrade Modulus

As illustrated in Figure 1, most of the data-points are concentrated on the equality line with the exception of a limited number of data-points corresponding to modulus values higher than 50,000 psi. To differentiate even better between the points closer to the equality line – which denote good agreement between the two pieces of equipment; and the data-points denoting poor agreement, the plot can be re-done in arithmetic scale, as shown in Figure 2:

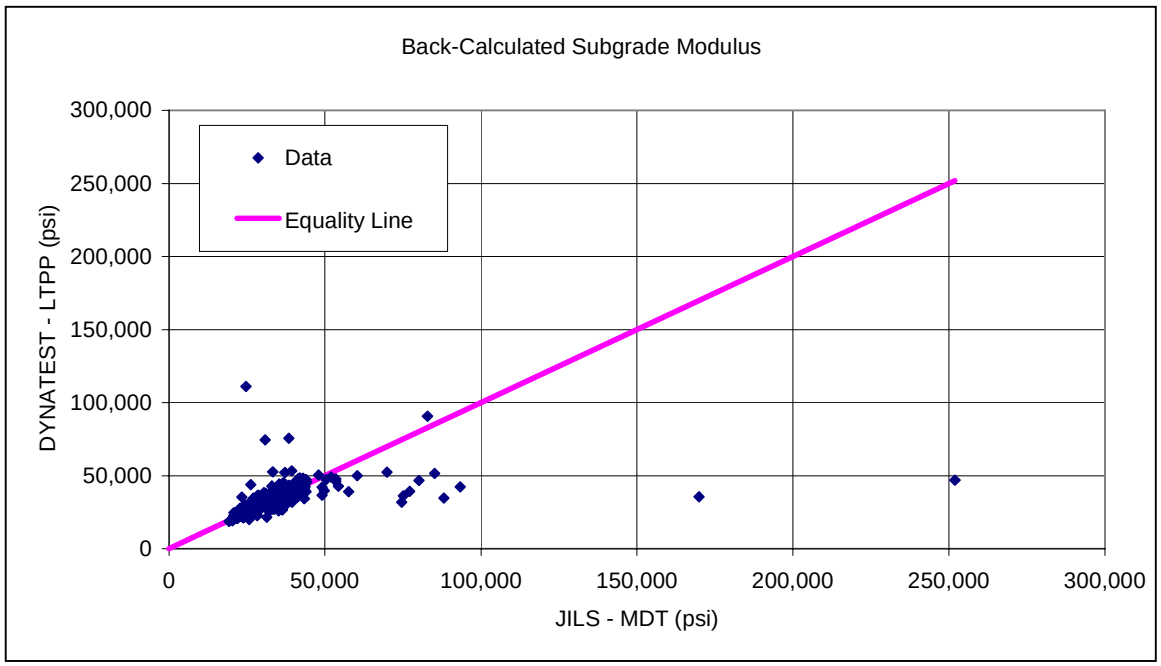


Figure 2. Subgrade Modulus (Arithmetic Scale)

It is obvious from Figure 2 that the good agreement between the two devices is lost only for moduli values higher than 50,000 psi. These relatively high values may very well be considered outliers because the typical moduli values for subgrade materials are well below 50,000 psi

To see the effect of removing these data points on the correlation, the data is plotted again in logarithmic scale and the coefficient of determination R^2 is calculated, as shown in Figure 3:
As shown in Figure 3, the coefficient of determination R^2 increases from 0.43 (Figure 1) to 0.69

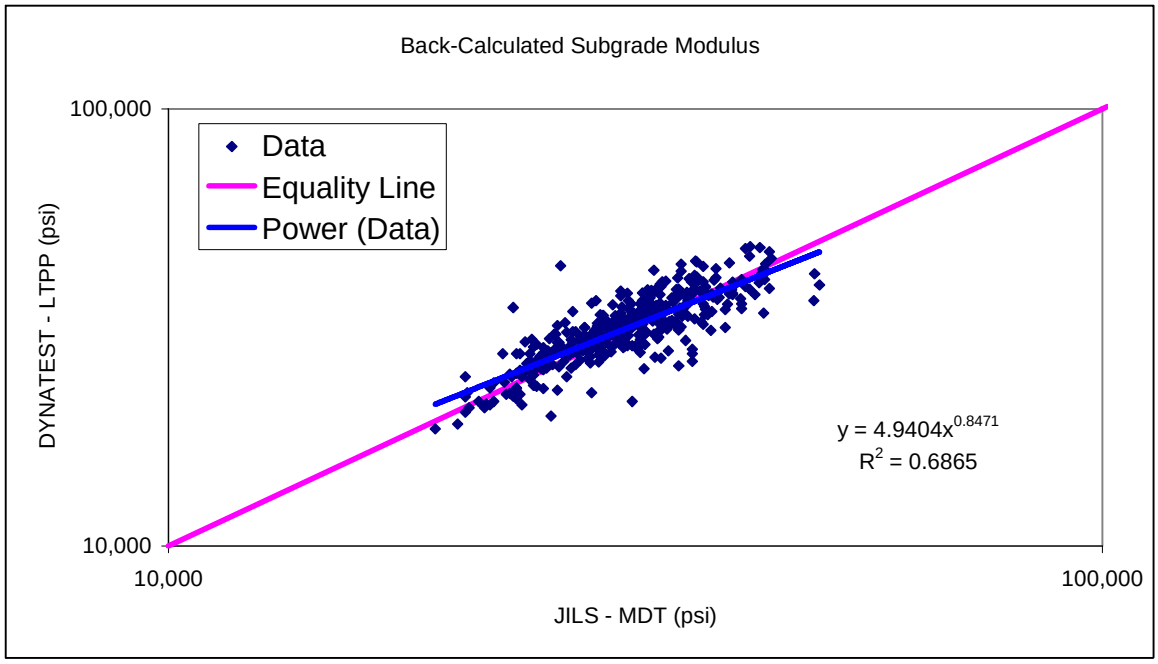


Figure 3. Subgrade Modulus (Reduced Data)

However, the purpose of this comparison was to investigate if bias exists between the two devices. In other words, if, on the average, the to pieces of equipment will produce the same estimate of the modulus of the subgrade. And, as shown in Figures 1 through 3, there is no significant bias – i.e. data-points are concentrated on the equality line and equally distributed on both side of the equality line.

The R^2 value of 0.69 shows that there is scatter in the data and that the correlation is not perfect – in which case the R^2 value would be 1. The sources of scatter most likely come from both pieces of equipment and there is no indication or reason to state that one is better than the other.

Task 5 – Presentation of Work Plan to MDT

Completed: A PowerPoint Work Plan was presented to MDT by the project team in October 2001.

PHASE II: CURRENT WORK ACTIVITIES AND COMPLETED TASKS

Task 6 – Implement the Work Plan – Data Collection

LTTP Sites

There are 93 LTPP sites included in the experimental factorial. Of these, 39 are located in Montana and 54 in neighboring States and Canada. A set of queries was written that can be used at any time in the future to extract the data needed from the LTPP database to update the

information in the calibration/validation database. The database is now complete and populated with LTPP data.

Non-LTPP Sites
The 10 non-LTPP sites are:

- Condon
- Deerlodge / Beckhill
- Silver City
- Roundup
- Lavina
- Wolf Point
- Ft. Belknap
- Perma
- Geyser
- Hammond

All testing related to the 10 sites is complete and the results have been presented in previous progress reports.

Superpave Sites
In addition to the 10 non-LTPP sites, two Superpave sites have been selected for inclusion in the testing/monitoring plan. These sites are Lothair and Baum Road. Samples of material from the two sites were received from MDT during 2003 consisting of cans of binder, bags of bulk mix, and buckets with unbound material. The materials have been stored off site in a temperature-controlled facility.

Binder testing results from Trumbull (Granite City, Illinois) for the three Superpave mixture tests were presented in the May 2004 monthly report. Results of resilient modulus tests for the unbound materials were included in the September 2004 monthly report. Note that HMA cores were not available to test for indirect resilient modulus, tensile strength, and creep. However, gradation, volumetric properties, and viscosity can be used to predict the stiffness of the HMA layer using the Witczak et al. Dynamic Modulus predictive equation.

Task 7 – Data Analyses and Calibration of Performance Prediction Models

Completed: The calibration technique (the specific steps required to determine calibration coefficients) was demonstrated to MDT utilizing models similar in nature to the NCHRP 1-37A *Mechanistic-Empirical (M-E) Pavement Design Guide* (initially titled *2002 Design Guide*) models. The project team made this presentation to the MDT in August 2003 along with a progress report, findings, and an illustration of the calibration exercise for the Silver City test section. A detailed discussion of the calibration algorithm accompanied by examples and step-by-step instructions will be included in a chapter of the Final Report.

In August 2004, a project meeting update and status report was held at MDT's headquarters. An overview of the work completed to date and a presentation on the calibration process as well as the results obtained to date were presented. A demonstration of the new M-E Pavement Design Guide software was provided to identify the complexity, detail the inputs, and note some of the problems that may be encountered by MDT personnel using the software for selected pavement types.

The calibration and validation database has been finalized and populated with LTPP data. The latest version of the calibration/validation database was given to MDT (CD format) at the August 2004 meeting.

An initial performance prediction exercise was performed for the 10 non-LTPP experimental sites. Material test data together with historical traffic and climatic data were used to predict the performance of these sites in terms of fatigue cracking and rutting in the asphalt concrete layer and rutting in the base and subgrade layers. Predicted distress was compared to results of the two distress surveys available for these sites (June 2002 and June 2003) and to the rutting measurements taken in October 2001. The results of this exercise were included in the July-September 2003 Quarterly Report.

A second performance prediction analysis, similar to the one performed on the non-LTPP sites, was started on the LTPP experimental sites. The availability of LTPP data was investigated in parallel with this study. While the performance predictions could be done either by spreadsheets or using the M-E Design Guide software, the solution by spreadsheets was used primarily because the Design Guide software was not available at that time. However, after a review and revision of the project budget during the month of April, 2004, the study was suspended. The team considered the performance predictions that will be performed using the M-E Design Guide software to be of greater importance, and the funds available will be allocated to this effort.

The review edition of the M-E Design Guide software was released by NCHRP in mid-July 2004. The research team used the software to begin the calibration analyses for the performance models included in the M-E Design Guide.

The project team will complete a simplified calibration exercise using the same distress prediction models, but in a more simplified manner so that MDT can use this information with their pavement management database. This activity will be demonstrated to MDT during the final meeting and will be included in the final report submitted for review.

Task 8 – Final Report and Presentation of Results
No activity.

PROBLEMS / RECOMMENDED SOLUTIONS

No problems were encountered during last month and none are anticipated next month.

NEXT MONTH'S WORK PLAN

The activities planned for next month are listed below:

- Coordinate with MDT personnel on an as-needed basis.
- Continue the calibration analyses
- Retrieve FWD test data for 2005
- Plan for a comparison study of the Profile equipment
- Plan for the last distress survey of the 12 non-LTPP sites

FINANCIAL STATUS

The Financial Summary I table shows the estimated expenses incurred during the reporting period.

The Financial Summary II table provides the total project expenditures by the Montana and FHWA fiscal years in comparison to the allocated funds for each fiscal year.

The Financial Summary III-A chart illustrates total expenditures from inception of the project June 2000 through December 2003. The Financial Summary III-B chart reflects total project expenditures from January 2004 to the end of the project, May 2006.

cc: Jim Moulthrop, Fugro
Dragos Andrei, Fugro
Amber Yau, Fugro
Veena Prabhakar, Fugro
Harold Von Quintus, ERES/ARA
Jon Watson, MDT
Greg Zeihen, MDT
Dan Hill, MDT
Matthew Witczak, Consultant
Mark Hallenbeck, Consultant

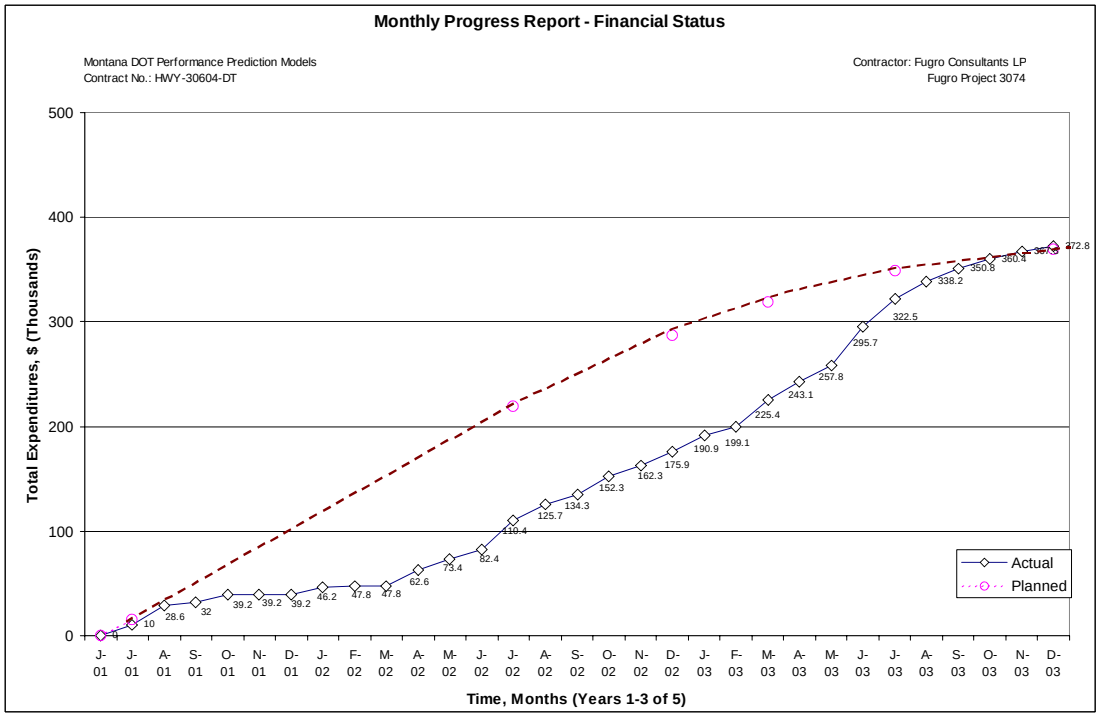
Financial Summary I
Estimated Expenses for Reporting Period: Fugro Consultants LP

Cost Element	End Quarter-4 2004 Cumulative Project Costs, $	Quarter-1 2005 Expenditures, $	Cumulative Project Costs, $
Direct Labor	102,760.04	224.00	102,984.04
Overhead	146,946.74	320.32	147,267.06
Consultants/Subcontractors	54,632.58	0.00	54,632.58
ERES/ARA	31,220.04	0.00	31,220.04
Parsons-Brinckerhoff	12,092.58	0.00	12,092.58
SME	523.21	0.00	523.21
Matthew Witczak	2,850.00	0.00	2,850.00
Mark Hallenbeck	6,746.75	0.00	6,746.75
Brent Rauhut	1,200.00	0.00	1,200.00
Travel	15,507.03	0.00	15,507.03
Testing	75,690.48	0.00	75,690.48
Other Direct Costs	7,398.36	0.00	7,398.36
Fee	39,505.11	54.43	39,559.54
TOTAL	442,440.34	598.75	443,039.09

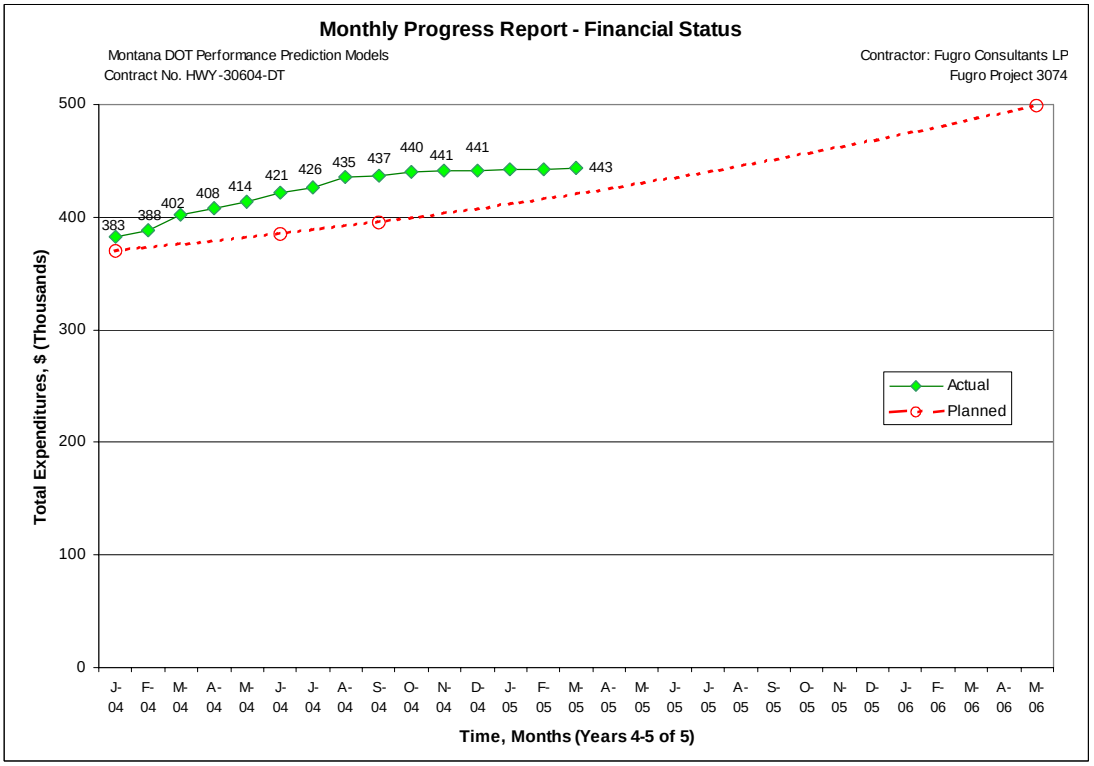
Financial Summary II
Total Expenditures by Fiscal Year: Montana and FHWA

MONTANA DOT FISCAL YEAR			FHWA FISCAL YEAR		
Fiscal Year	Cumulative Allocated Funds, $	Cumulative Expenditures, $	Fiscal Year	Cumulative Allocated Funds, $	Cumulative Expenditures, $
6/1/2000-6/30/2001	15,000	*0	6/1/2000-9/30/2001	65,000	31,996
7/1/2001-6/30/2002	218,969	82,420	10/1/2001-9/30/2002	258,969	102,303
7/1/2002-6/30/2003	348,969	213,291	10/1/2002-9/30/2003	358,969	216,187
7/1/2003-6/30/2004	388,969	125,486	10/1/2003-9/30/2004	398,969	86,695
7/1/2004-6/30/2005	428,969	21,842	10/1/2004-9/30/2005	438,969	5,857
7/1/2005-6/30/2006	498,969	0	10/1/2005-9/30/2006	498,969	0
TOTAL	498,969	443,039.09	TOTAL	498,969	443,039.09

*June 2001 expenditures were combined with July 2001 expenditures.



Financial Summary III-A: Total Expenditures by Month Jun 2000 – Dec 2003



Financial Summary III-B: Total Expenditures by Month Jan 2004 – Mar 2006